New Technology under the Chassis
The Science in the Suspension

by

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The Command College Futures Study Project is a FUTURES study of a particular emerging issue of relevance to law enforcement. Its purpose is NOT to predict the future; rather, to project a variety of possible scenarios useful for strategic planning in anticipation of the emerging landscape facing policing organizations.

This journal article was created using the futures forecasting process of Command College and its outcomes. Defining the future differs from analyzing the past, because it has not yet happened. In this article, methodologies have been used to discern useful alternatives to enhance the success of planners and leaders in their response to a range of possible future environments.

Managing the future means influencing it—creating, constraining and adapting to emerging trends and events in a way that optimizes the opportunities and minimizes the threats of relevance to the profession.

The views and conclusions expressed in the Command College Futures Project and journal article are those of the author, and are not necessarily those of the CA Commission on Peace Officer Standards and Training (POST).

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There are few thrills like the feeling of racing down a highway in pursuit of a bad guy. Being mindful to always stay within policy, watching the speedometer rise raises the heart rate and increases the feeling you are glad you didn't take that position with the Postal Service. Your Ford V8 engine is singing beautifully, and the automatic transmission is doing just what it's supposed to do. While you practice your push-pull steering, like you were trained in the academy, you haven't given one thought to the most important component on this "Mr. Toad's Wild Ride" you are on: the suspension.

Largely unexposed, the suspension system on your patrol car is tasked with keeping the wheels in solid contact with the ground. It is a simple job; keep four small patches or tire in contact with the roadway surface regardless of what comes in the way. Suspension components such as ball joints, idler arms, sway bars, axle shafts, wheel bearings and tie rods are all susceptible to damage from driving on damaged roads. So as you are hitting that pothole at 65 MPH, you barely give a thought to the stresses and forces at work under the frame of your patrol car. What you may not have ever considered is the reactive suspension in your patrol car is cutting edge technology. . . provided you were driving your patrol car in the 17th century (Haroon and Adams, p 1). So while the 400 cubic inch, eight cylinder monster in the Matador, or the reliable and revered 350 in the wide selections of Chevys used for police service have morphed in a 4.6 liter powerplant able to crank out incredible power and sip a little lighter on the fuel, we haven't really pushed for a better method to keep those tires planted on Terra Firma. The future of our new patrol vehicles lies more with suspension than horsepower. Let's look under the chassis.

What is Really under the Chassis

So, where did the idea for springs, shocks and suspensions come from? Prior to the 1600's carriages were mounted directly on the axles. Many common people choose to walk or ride a horse. There were few maintained roads and travelling by carriage could be painful. According to Horse Drawn Carriage magazine, King Matthias commissioned a carriage builder to suspend the body from the axles with leather straps. The configuration would be similar to leaf springs on a modern truck. The addition of a "C" spring in the late 1600's significantly increased the riding comfort. As we moved to the automobile in the 20th Century, the 17th Century concepts were modernized, but never fundamentally changed from their predecessors. Until 1901 when C. L. Horock developed the telescoping shock absorber (Infoplease Article, 2010, 1).

The most significant improvement in suspension systems since the horse and buggy days is the shock absorber. Shocks are generally hydraulically operated, meaning they are filled with fluid. This fluid is forced through a valve as the shock moved up and down to dampen the effects of imperfections in the road (like potholes, dips at the gutters) and climbing over curbs in your patrol car to get into the local park to look for graffiti bandits. Shocks play a vital role to keep the wheels connected to the ground by dampening the energy stored in the coiled springs. As your vehicle compresses the springs, they store energy that will need to be released. Without a shock absorber or strut (a strut provides the same shock dampening as a shock but a strut also controls side load that a shock cannot), the spring would release all its energy at one time. Considering Newton and his "equal and opposite reaction" concept, that pothole would help launch that wheel right back into the ground. Imagine the thrill of the front of your car rising to meet the evening sky as you blast over a deep gutter at an intersection. Without the shocks offsetting the effect of the momentum created by the release of pressure in the springs, you would go into the wild blue yonder, at least for a few feet. This simple dampening effect of the shock helps retain steering control. Unfortunately, in the most widely-used vehicles for police service, the suspension is largely the same as that for any other passenger car.

The Ford Crown Victoria was designed as a passenger car in 1993, not as a patrol vehicle (Ford Buyers Guide 1993). The suspension was “soft” to help with driving comfort. When Chevrolet discontinued the Caprice, Ford was set to dominate the rear wheel drive, full sized sedan market. But the hard driving world of law enforcement needed more stability to give the officer positive control over a vehicle that would be driven over rough roads or off road, as well as on paved city streets. This brought about the stiffer suspension in the Crown Victoria Police Interceptor (CVPI) (Michael Moussa, 2011).

The “harder” shocks and stiffer suspension components did a great job in the wheel-road contact area but an unintended consequence for this stiffer ride was transferring those forces to the shock mounts and frame of the CVPI (Michael Moussa, 2011). Those forces produced by the harder shocks and stiffer springs created more pressure on the shock mounts than the Ford engineers originally intended. With the addition of braces to support the original mounting brackets and heavier mount bearings there is mitigated damage to these structures (Interview with Mike Moussa, 2011).

But our shrinking budgets force us to squeeze more miles out of a fleet. Many cities were changing out patrol cars at 70,000 miles but now patrol vehicles are being driven 100,000 miles or more. For instance, the Los Angeles Sheriff’s Department Technical Service Division Fleet Management section reported their patrol vehicles had been retired out at 100,000 miles are now being pushed 150,000 miles. The Monrovia CA Police Department had a procedure to replace the entire patrol fleet at three years of service, but have now elected to continue the service life of their patrol cars to five years or more. This means the miles driven would also significantly exceed 100,000. Since the CVPI is essentially a retrofit, and the frame and suspension were not necessarily designed for abuse of this length, how will they stand up to a service life they may not have intended to live? Unfortunately, there is no easy answer in re: emerging solutions. In fact, the quest for safety in suspensions has lasted for decades.

Active and reactive suspension systems

In 1980, Lotus engineers wanted to move from the traditional "reactive system" of shocks and springs to an "active system." In a reactive system, the wheel encounters a bump and the wheel retracts and after crossing over the bump the spring, dampened by the shock expands. An active system is constantly applying pressure downward to keep the tire in contact with the road. A computer controls the actuator at each wheel telling the actuator "... exactly when, which way, how far, and how fast to move" (Haroon and Adams, p 1). This computer technology makes the suspension of the vehicle proactive. Unfortunately, it also makes the vehicle heavier and the cost of the system was prohibitive. On top of the cost and weight increase there was the need for a hydraulic pump that took valuable horsepower away from the, then, rear wheels. In the end the system could not respond quickly enough to deal with the small jolts that hammer the system during every day driving.

In the 1990's, Infiniti also tried to commercialize an active system. Infiniti's system weighed a mere 202 pounds however the cost rocketed to $5500. It also adversely impacted fuel economy by taking 5 horsepower to power the system. Infinity discontinued their version of an active system when the Q45 went out of production in 1996. Now only the high-end Mercedes have an active system. Called the active body control (ABC) system, it is the closest thing to an active system on the market (Car and Driver, 2004).

There are more recent efforts to enhance suspension utility and safety. The Levant Power Corporation in Boston MA is developing a product called the “GenShock” to replace traditional shock absorbers. The GenShock uses the power of the hydraulic fluid forced through the valve to turn a turbine to provide electricity for the vehicle to use (Levant Power, 2010). This system will certainly help hybrid vehicle owners, and there may be a great use in powering the ever-increasing amount of electronic gear found in the modern patrol car. While we wait for a better system to help keep the patrol car reliably connected to the ground, Genshock could at least help power the myriad of devices and electronic tools seen in a contemporary patrol vehicle. But the issue remains; we still need an active suspension for safer operations under the high speed environment of police work.

While getting power from the shocks might be refined thinking, the future of active vehicle suspension may come from the sound system. More precisely, it may come from one of the pioneers of amplified sound. Doctor Amar G. Bose, founder of the Bose Corporation, is exploring the use of electromagnetics as a means of providing a fast, reliable suspension over a wide variety of surfaces and driving conditions. Dr. Bose had a fascination with automobile suspensions for many years. He owned a 1958 Pontiac with Ever-Level air suspension and a Citroen that used a hydro-pneumatic suspension (Car and Driver 2004). From this experience, he initiated a mathematical study project to identify an ideal suspension in the 1980’s. The study’s conclusion was that electromagnetics could provide the answers other had been seeking.

According to the Bose Corporation, the suspension envisioned “…required significant advancements in four key disciplines: electromagnetic motors, power amplifiers, control algorithms and computation speed" (Bose Corporation, p 1). Bose was certain they could figure out a way to develop the first three components, and they made the assumption that the computer world would catch up. The electromagnetic linear actuator, then, was the answer they proposed.

The science of linear electromagnetic actuators, though, was unheard of in motor vehicles. Magnets and coils of wire are used to extend and retract the motor components. This can be done at a speed far greater than the hydraulic method. Bose claims their system can move the actuator "8.5 inches and over 100 times per second and only use 2 horsepower" from the engine (Car and Driver 2004). Besides responding to the bumps and jolts of driving down the road, the system can handle the pitch and roll of aggressive driving, similar to what you would encounter in a pursuit or a high priority call for service. Attached to the electromagnetic motor is an amplifier that will power the motor to extend the shock and receive the power back as the shock is retracted. According to Bose the suspension requires less than a third of the power of a typical vehicle's air conditioning system (Bose Corporation, p 2). This whole process is controlled through mathematical algorithms developed throughout the 24 years of research and a company investment of over $100 million (Bose Corporation, p2). Their prototype system is still very heavy and very costly. Linear electromagnetic motors, amplifiers and algorithms, though, combine to provide the comfort you cannot find in a hard suspension vehicle like current patrol vehicle with the steering control of that hard suspension.

There have been great advancements in the engines powering our next generation patrol car. Vehicles will provide more horsepower with few cylinders and still provide improved gas mileage. Transmissions have overdrive for increased fuel economy. But the suspension system has yet to move out of that 17th Century carriage. The Bose system is an exciting concept. Test vehicles with the Bose actuators have been able to jump parking lot bumpers and still retain control of the vehicle. The functional system, though, is still years away. While the new police vehicles produced by Ford, Chevrolet and Carbon Motors are vying to fill the role for the next "great" patrol vehicle, the suspension system cannot be overlooked. As law enforcement agencies stretch the last miles out of their CVPI's, fleet managers need to lobby the next generation manufacturers to improve the suspension of the replacement vehicles on the horizon.

Conclusion

With departments holding on to their patrol fleets longer to forestall buying new vehicles and cities finding the resurfacing and upgrades to the roadway surfaces a greater challenge, police vehicles need the type of precision suspension that Bose is working on. Ford said it best in their brochure for the new Police Interceptor, "Remember that even advances in technology cannot overcome the laws of physics. It is always possible to lose control of the vehicle due to inappropriate driver input for the conditions." But if we can keep the wheels in touch with the roadway surface we may be able to avoid some loss of control.

With the production of the Ford Crown Victoria and its Police Interceptor package coming to an end, we are looking to the future for the next great patrol vehicle. The automotive industry is looking to make the next "best" vehicle for law enforcement. It will need a motor that can still do 120 miles per hour, a frame that can support a PIT maneuver, a transmission to maximize the smaller powerful engine. As we now know, it will also need an active suspension system to keep all four wheels in contact with the ground.

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